Use of agricultural by-products in broiler diets: A sustainable approach to poultry nutrition

Uso de subproductos agrícolas en dietas para pollos de engorde: un enfoque sostenible para la nutrición avícola

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Abstract

Feed accounts for the major portion of broiler production costs, highlighting the urgent need to identify alternative and cost-effective resources. At the same time, a considerable volume of agricultural by-products is generated annually, which, if not properly utilized, contributes to environmental pollution. The incorporation of agricultural by-products into poultry diets offers a sustainable strategy for reducing feed costs while improving environmental indices. In addition to their nutritional value, these by-products are rich in bioactive compounds such as polyphenols, flavonoids, and natural antioxidants that can enhance meat quality, immune status, and overall health in broilers. Studies have demonstrated that citrus pulp can be included in diets at levels up to 10% without adverse effects on growth performance or carcass yield, while improving antioxidant capacity and reducing cholesterol levels. Grape pomace, rich in phenolic compounds, has shown positive effects on lipid profiles and a reduction in meat lipid peroxidation. Tomato pomace, containing lycopene and natural vitamin E, increases dietary antioxidant capacity, improves immune responses, and reduces serum triglycerides. Likewise, olive pomace, particularly when combined with enzyme supplementation, enhances feed intake, body weight gain, lipid profiles, and liver function; in fermented forms, it further improves meat oxidative stability and economic efficiency. Overall, scientific evidence suggests that the optimized and processed use of agricultural by-products can not only reduce production costs but also contribute significantly to the sustainability of the poultry industry, mitigation of environmental pollution, and enhancement of global food security.

Keywords: Agricultural by-products, broiler chicken, meat quality, poultry nutrition.

Resumen

El alimento representa la mayor parte de los costos de producción de pollos de engorde, lo que resalta la urgente necesidad de identificar recursos alternativos y rentables. Al mismo tiempo, se genera anualmente un volumen considerable de subproductos agrícolas que, si no se utilizan adecuadamente, contribuyen a la contaminación ambiental. La incorporación de subproductos agrícolas en las dietas avícolas ofrece una estrategia sostenible para reducir los costos de alimentación y, al mismo tiempo,

mejorar los índices ambientales. Además de su valor nutricional, estos subproductos son ricos en compuestos bioactivos como polifenoles, flavonoides y antioxidantes naturales que pueden mejorar la calidad de la carne, el estado inmunitario y la salud general de los pollos de engorde. Estudios han demostrado que la pulpa de cítricos puede incluirse en las dietas en niveles de hasta el 10% sin efectos adversos en el crecimiento ni el rendimiento de la canal, a la vez que mejora la capacidad antioxidante y reduce los niveles de colesterol. El orujo de uva, rico en compuestos fenólicos, ha mostrado efectos positivos en los perfiles lipídicos y una reducción de la peroxidación lipídica de la carne. El orujo de tomate, que contiene licopeno y vitamina E natural, aumenta la capacidad antioxidante de la dieta, mejora la respuesta inmunitaria y reduce los triglicéridos séricos. Asimismo, el orujo de aceituna, especialmente al combinarse con suplementos enzimáticos, mejora el consumo de alimento, la ganancia de peso corporal, el perfil lipídico y la función hepática; en forma fermentada, mejora aún más la estabilidad oxidativa de la carne y la eficiencia económica. En general, la evidencia científica sugiere que el uso optimizado y procesado de subproductos agrícolas no solo puede reducir los costos de producción, sino que también contribuye significativamente a la sostenibilidad de la industria avícola, la mitigación de la contaminación ambiental y la mejora de la seguridad alimentaria mundial.

Palabras clave: Subproductos agrícolas, pollo de engorde, calidad de la carne, nutrición avícola.

Introduction

Feed accounts for more than 60–70% of broiler production costs; therefore, the use of alternative resources to reduce these expenses is of great importance (Pinheiro et al., 2008). At the same time, a vast amount of agricultural by-products is generated annually, a considerable proportion of which can be recycled in the food and livestock industries (Erinle, 2022). The Use of these by-products, within the framework of sustainable agriculture and the circular economy (economic circle), not only reduces production costs but also mitigates environmental pollution (Herrero-Encinas et al., 2020). The continuous growth of the human population and the increasing demand for animal protein have further raised the demand for conventional feedstuffs such as corn and soybean meal, intensifying both economic and environmental pressures on production systems (Mottet & Tempio, 2017). In this context, the use of alternative feed resources, particularly agricultural by-products, has been increasingly recognized as a sustainable and cost-effective strategy by researchers and producers (Salami, 2019). Agricultural by-products include pomaces and residues derived from food industries and crop processing, such as citrus pulp, tomato pomace, grape pomace, olive pomace, and cassava residues. A large portion of these materials is discarded without proper utilization, contributing to environmental contamination (Saini et al., 2025). Incorporating such by-products into poultry diets not only aids in waste management and reduction but also generates substantial economic value and decreases dependency on imported feed resources (Ravindran & Blair, 1992). Beyond economic benefits, these by-products contain bioactive compounds such as polyphenols, flavonoids, and natural antioxidants, which play an important role in enhancing poultry health, improving meat quality, and boosting immune responses (González-Gallego et al., 2010). For instance, grape and olive pomace are rich in phenolic compounds that improve the antioxidant status of broilers and help prevent lipid oxidation in meat (Habib et al., 2023). Likewise, tomato pomace, due to its lycopene and carotenoid content, contributes to improved immune responses and reduced oxidative stress (Hosseini-Vashan et al., 2016). From an environmental perspective, the inclusion of agricultural by-products in poultry diets represents a crucial step toward sustainable farming and reducing the pollution caused by their disposal (FAO, 2013). Many countries, aiming to achieve circular economy goals and promote green production, have moved toward

replacing conventional feed resources with agricultural residues (Makkar, 2018). Furthermore, their utilization in broiler production can reduce the carbon footprint of chicken meat and enhance sustainability indicators within agricultural and food systems (Van Zanten, 2019). Despite these advantages, direct use of agricultural by-products may pose certain limitations due to their high fiber content, presence of antinutritional factors, or variability in chemical composition (Iyayi & Davies, 2005). Therefore, processing methods such as fermentation, enzymatic treatment, or drying are essential to improve their nutritional value and enhance digestibility and nutrient availability for broiler chickens (Yasmeen & Ahmad, 2025).

Citrus Pulp

Citrus pulp is a rich source of pectin, soluble fiber, and phenolic compounds. Studies have shown that including low levels of citrus pulp in broiler diets can improve gut quality and immune indices without significantly compromising growth. In addition, standardized citrus extracts have been reported to exert positive effects on meat quality and overall poultry health (Diaz-Vargas et al., 2018). As a by-product of the citrus industry, citrus pulp has been evaluated in broiler nutrition, demonstrating both benefits and some limitations. Incorporation of citrus pulp into broiler diets at certain levels can be advantageous without negatively affecting performance, carcass yield, or meat quality, while also offering economic and environmental benefits through the utilization of agricultural residues. Citrus pulp can be safely included up to 10% in broiler diets from day 1 to 42 without adverse effects on performance or carcass traits (Diaz-Vargas, Murakami, Pintro, Ospina-Rojas, de Souza & Eyng, 2018). However, higher inclusion levels of dried lemon pulp (DLP) have been associated with reduced body weight and impaired feed conversion ratios, particularly at levels above 7.5% (Basir & Toghyani, 2017). Citrus pulp, especially orange pulp, improves the oxidative stability of broiler meat due to its phenolic compounds that delay lipid oxidation (Zoidis et al., 2022). While it does not significantly affect meat sensory properties, it enhances nutritional quality by increasing polyunsaturated fatty acids (Ahmed Readh et al., 2024). Inclusion of citrus pulp up to 10% does not negatively influence blood parameters and, in some cases, reduces cholesterol levels. Furthermore, dried orange pulp (DOP) has been shown to improve serum antioxidant status and reduce cholesterol and triglyceride levels (Readh et al., 2023). Overall, the economic indices of broiler production improve with the incorporation of citrus pulp, making it a cost-effective feed ingredient (Diaz-Vargas et al., 2022).

Grape Pomace

Grape pomace, due to its high content of polyphenols and anthocyanins, is recognized as a natural antioxidant. Research has indicated that its inclusion can reduce meat lipid peroxidation and improve carcass quality (Gungor, 2021). Fermentation of grape pomace with fungi has been shown to enhance digestibility and increase its positive impact on growth performance (Herrero-Encinas, Blanch, Pastor & Menoyo, 2020). The incorporation of grape pomace in broiler diets has been associated with beneficial effects, particularly on antioxidant status, lipid profile, and meat quality, suggesting its role as a natural antioxidant that supports broiler health and performance. Rich in polyphenols, grape pomace increases antioxidant activity in broilers by elevating the levels of enzymes such as superoxide dismutase and catalase. In terms of performance and carcass yield, grape pomace did not adversely affect body weight or carcass traits, although it was linked to lower feed intake and feed conversion ratios, which may influence overall growth efficiency (Şen & Başalan, 2022). This antioxidant enhancement is crucial for reducing oxidative stress, thereby improving overall health and meat quality. Supplementation with grape pomace has also

been associated with significant reductions in low-density lipoproteins (LDL) in the blood, positively impacting cholesterol levels (Dupak et al., 2021). Although some studies did not find significant differences in meat lipid oxidation, a slight reduction in malondialdehyde levels was reported, indicating potential benefits in meat preservation (Jurčaga et al., 2021). The amino acid and fatty acid profiles of broiler meat were largely unaffected, though improvements in specific fatty acids such as oleic acid have been observed (Haščík et al., 2023).

Tomato Pomace

Tomato pomace contains lycopene and natural vitamin E, which can enhance the antioxidant capacity of poultry diets. Studies have shown that its inclusion under heat-stress conditions improves growth performance and reduces oxidative stress in broilers (Erinle, 2022). Controlled supplementation with tomato pomace has also been reported to improve meat quality (Gungor, 2024). Tomato pomace contains lycopene and natural vitamin E, which can enhance the antioxidant capacity of poultry diets. Studies such as Mohammed et al. (2021) reported that inclusion up to 6% did not negatively impact growth, while Boulaajine et al. (2024) found beneficial effects at 5–15% levels, especially during the early growth stage. Similarly, Basir & Toghyani (2017) observed that higher levels above 7.5% could impair body weight and feed conversion ratios. These results indicate that safe inclusion levels of tomato pomace are generally between 5–7.5% without adverse effects, while levels up to 10% may still be acceptable depending on processing and enzyme supplementation. When an ingredient shows reduced performance at higher concentrations but still presents health-promoting properties (e.g., antioxidant and immunomodulatory effects), it may be considered not only as a feed component but also as a functional feed additive. Therefore, it is important to connect findings by highlighting both the nutritional limitations and the potential functional applications of tomato pomace in broiler diets. Moreover, supplementation with 5% DTP improved serum biochemical parameters by reducing triglycerides and increasing HDL cholesterol. At this level, immune responses and antioxidant status were enhanced, as indicated by elevated activities of glutathione peroxidase and superoxide dismutase and reduced malondialdehyde levels (Hosseini-Vashan, Golian & Yaghobfar, 2016). The addition of enzymes to DTP-based diets further improved immune parameters and reduced abdominal fat. Economically and practically, tomato by-products are cost-effective feed ingredients that can be included in balanced diets without adverse effects on performance (Maha et al., 2018). However, the high fiber content of tomato pomace must be considered, as improper inclusion may lead to undesirable effects (Sahragard et al., 2023).

Olive Pomace

Olive pomace, a by-product of olive oil production, has been investigated for its potential benefits in broiler diets, demonstrating positive effects on growth performance, health, and economic efficiency. Olive by-products, including olive pomace and olive pomace oil, are rich in polyphenols and beneficial fatty acids. Studies have shown that when supplemented with fibrolytic enzymes, olive pomace can improve growth performance and nutrient digestibility (Brenes, 2008). Additionally, olive pomace oil can serve as a substitute for conventional vegetable oils, improving the fatty acid profile of broiler meat (Abd El-Hack, 2017). Inclusion of olive pomace in broiler diets, particularly in combination with enzyme supplementation, enhances growth performance, improves serum lipid profiles, and supports overall health without negative effects on productivity, making it a promising option for sustainable poultry production. Inclusion levels of up to 10% have shown no adverse impact on growth, while multi-enzyme supplementation further enhanced feed intake, body weight, and weight gain (Ghaffar et al., 2025). Fermented olive pomace, particularly when enzymatically

treated, has been found to improve body weight gain and feed conversion ratios, with optimal results observed at 7.5% and 15% inclusion levels. Fermentation also enhanced the oxidative stability of frozen meat by increasing antioxidant enzyme levels and extending storage life (Ibrahim et al., 2021). From an economic standpoint, fermented olive pomace reduced feed costs and improved profitability (Ibrahim et al., 2021). Health benefits include improved blood lipid profiles, with reductions in LDL cholesterol and increases in HDL levels (Habib, Al-Zamili & Al-Gharawi, 2023). Olive pomace supplementation also reduced plasma ALT and AST levels, indicating improved liver function (Abdelkarim et al., 2025). Furthermore, olive pomace extract has been shown to mitigate adverse effects on gut health, such as increased intestinal permeability under stress conditions like fasting (Herrero-Encinas, Blanch, Pastor & Menoyo, 2020). In terms of meat quality, the use of olive pomace acid oil preserved meat sensory attributes and lipid stability (Albendea et al., 2023). Despite these advantages, the high fiber content of olive pomace may limit its use as a primary feed ingredient; however, when used in moderation and combined with enzymatic treatments, it can improve broiler performance and health. Moreover, the utilization of olive by-products contributes positively to environmental sustainability in poultry production (Mahasneh et al., 2024).

Conclusion

The utilization of agricultural by-products in broiler diets represents a sustainable and economically viable strategy for the poultry industry. Research findings indicate that the inclusion of optimal levels of citrus, grape, tomato, and olive pomaces can enhance growth performance, immune responses, meat quality, and antioxidant status of broilers, while simultaneously reducing feed costs and the environmental burden associated with waste disposal. Although the high fiber content and the presence of certain antinutritional factors may limit their direct use, appropriate processing techniques such as fermentation and enzymatic treatment can significantly improve their nutritional value and digestibility. Ultimately, the strategic and scientific incorporation of agricultural by-products into broiler diets can play a crucial role in promoting sustainable poultry production, reducing dependency on conventional feed resources, and supporting the achievement of sustainable development goals in agriculture and animal husbandry.

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